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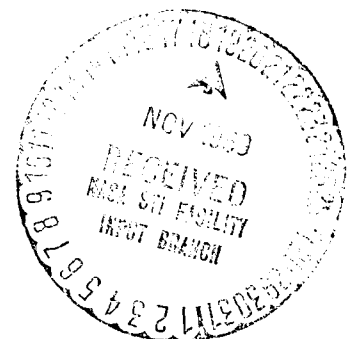
SUBJECT: Initial Humidity Buildup in the
AAP Cluster - Case 620

DATE: July 25, 1969

FROM: J. J. Sakolosky

ABSTRACT

The AAP Cluster, composed of the dry launched Saturn Workshop and a dependent CSM, is initially pressurized with dry gases from storage. This leads to a period early in the mission when the Cluster humidity level is below the minimum allowable level. This period can vary depending on the total water generation rate and total water removal rate of the Cluster. For a water generation rate of 15.6 lbs/day, the minimum allowable dew point of 45° F is reached in approximately 10 hours. At a water generation rate of 6.6 lbs/day (corresponds to three men at a metabolic rate of 500 Btu/hr each), an equilibrium dew point of 43° F is reached in three to four days.



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MEMORANDUM FOR FILE

INTRODUCTION

Initial pressurization of the AAP Cluster is accomplished through the use of oxygen and nitrogen which are stored in a dry condition (i.e., no water vapor present). This leads to a situation immediately following initial pressurization when the humidity level of the Cluster atmosphere is below the minimum specified by the MSC Crew Comfort Criteria. A dew point of 45° F is currently specified as the minimum allowable humidity level in the Cluster (Ref. 1).

Prolonged periods of operation under low humidity conditions can result in skin flaking, irritation, and general discomfort of the crew. It therefore becomes important to determine the length of time required following initial pressurization to reach the minimum allowable 45° F dew point.

A number of assumptions are made in this memorandum in order to simplify the analysis. Consequently, the results obtained are approximate. However, it is felt that the resulting level of accuracy is sufficient to provide a reasonable estimate of the time required for initial humidity buildup in the Cluster.

DISCUSSION

A flow schematic of the AM condensing heat exchangers and the molecular sieve system is shown in Figure 1. These are the only water removal sources considered operative in this analysis. Water lost overboard through normal atmospheric leakage is small by comparison (on the order of several tenths of a pound per day) and is ignored in this memorandum. The air stream flowing out of the condensing heat exchanger divides among three parallel branches -- the molecular sieve, an odor absorbing charcoal canister, and a flow by-pass. Air flowing back to the cabin atmosphere from the molecular sieve is assumed to be dry. Air flowing from the charcoal canister and parallel bypass is assumed to have the same water content as that flowing from the condensing heat exchanger.

(NASA-CR-106540) INITIAL HUMIDITY BUILDUP
IN THE AAP CLUSTER (Bellcomm, Inc.) 8 p

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When the dew point of the Cluster atmosphere is less than 40° F, no water is removed in the condensing heat exchanger. Thus, the only water removal source operative early in the mission is the predrying bed of the molecular sieve. When the dew point is greater than 40° F, the condensing heat exchanger water removal rate used in this analysis is based on data from Reference 2.

Water generation rates are based on crew metabolic activity. Results are shown for a high metabolic activity level during which considerable sweating takes place and for a lower level of activity corresponding to a metabolic rate of approximately 500 Btu/hr per man. The respective water generation rates are 15.6 lbs/3 men/day and 6.6 lbs/3 men/day. At the higher rate, approximately 9 lbs/day of the water produced is in the form of perspiration (Ref. 3). Atmospheric temperature is assumed constant at 70° F, and atmospheric composition is assumed to be uniform throughout the Cluster.

The initial buildup of water vapor partial pressure in the Cluster is shown in Figure 2. The equations describing the curves of Figure 2 are given in the Appendix. The partial pressure characteristic for each water generation rate is made up of two exponential curves -- one which applies below an atmospheric dew point of 40° F and a second which is applicable above a dew point of 40° F.

CONCLUSIONS

Water vapor content of the AAP Cluster will reach the minimum allowable dew point of 45° F in approximately 10 hours when the crew is working at a metabolic rate such that 15.6 lbs/day of water are generated. This corresponds to 5.2 lbs/day of transpired and perspired water per crewman. A more realistic water generation rate is probably a total of 6.6 lbs/3 men/day, corresponding to an average metabolic rate of 500 Btu/hr/man and no sweating. Under these conditions the dew point of the Cluster never does reach 45° F. An equilibrium dew point of approximately 43° F is reached in 3 to 4 days.

If these equilibrium humidity levels and the time to reach them are unacceptable from a crew comfort standpoint, several possible solutions deserve consideration. The most straightforward of these is to install a water evaporator in the Cluster. A pressurized launch of the Dry Workshop with a preconditioned atmosphere, or the storage of wet atmospheric supplies should also be given consideration.

J. J. Sakolosky
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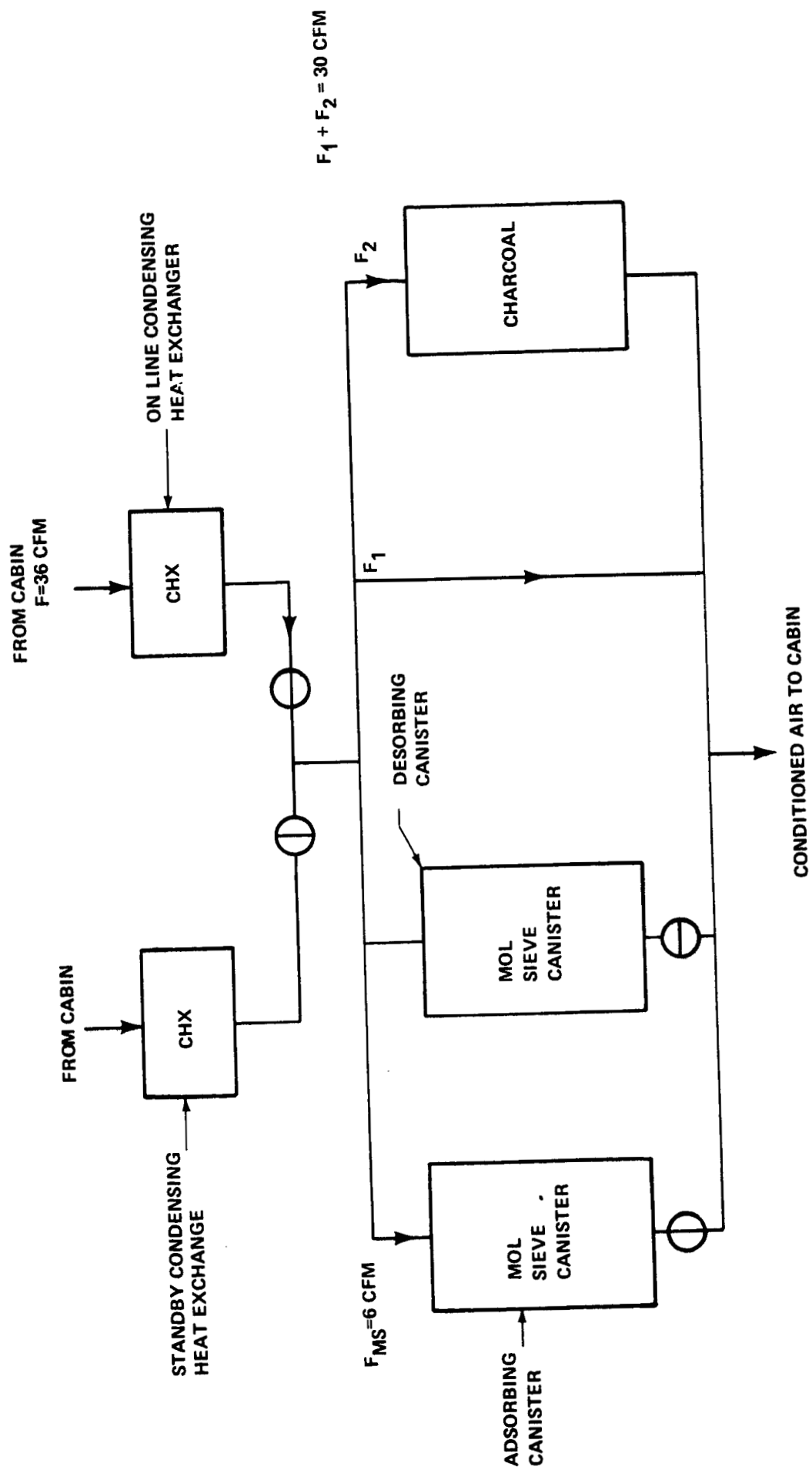


FIGURE 1- FLOW SCHEMATIC FOR THE CONDENSING HEAT EXCHANGER/MOLECULAR SIEVE SYSTEM

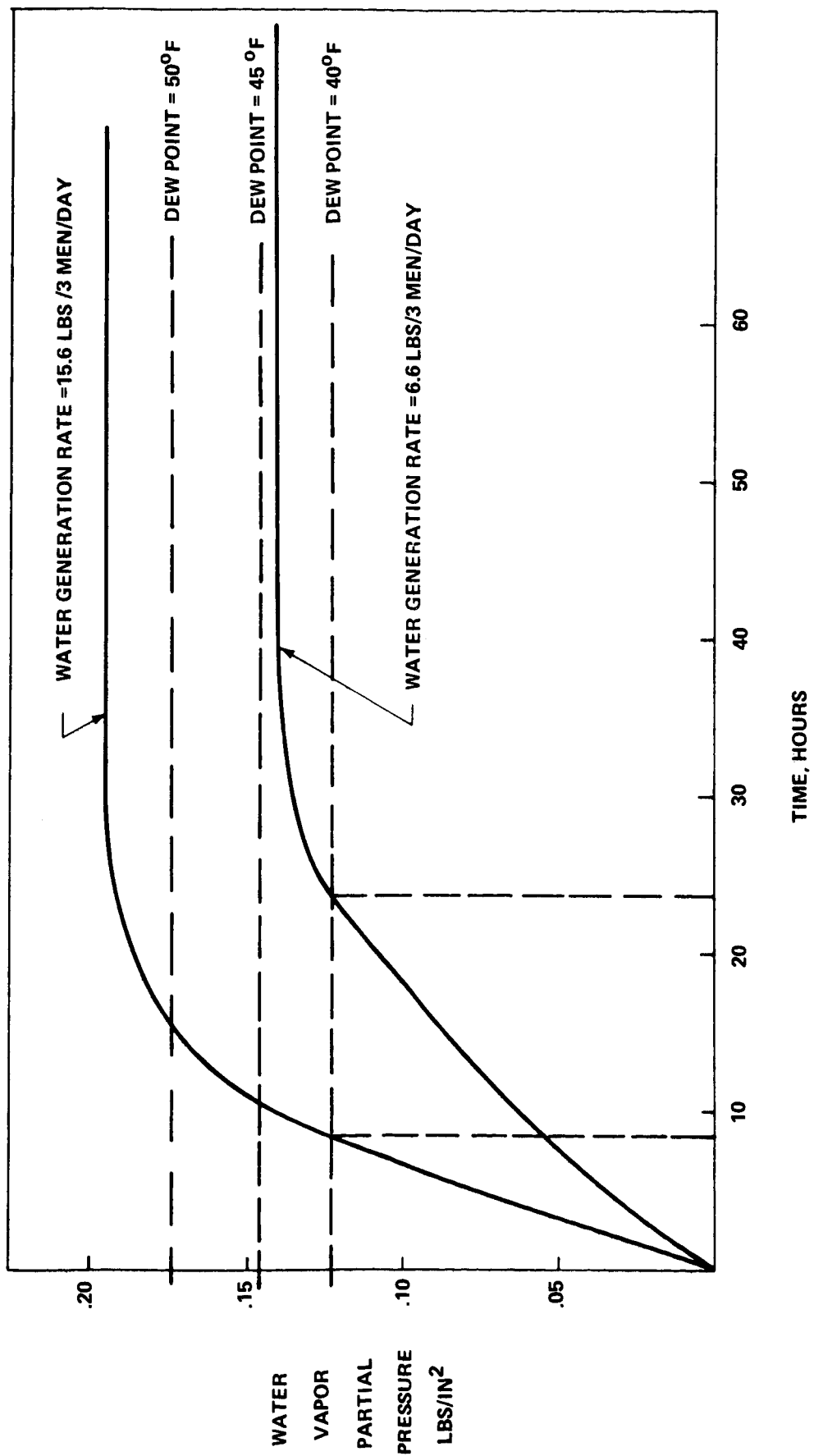


FIGURE 2- INITIAL HUMIDITY BUILDUP IN AAP CLUSTER

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APPENDIX: EQUATIONS DESCRIBING THE INITIAL HUMIDITY BUILDUP IN THE AAP CLUSTER

The general mass balance equation given below will be used to calculate the initial humidity buildup in the Cluster:

$$\frac{dm(t)}{dt} = g(t) - r(t) \quad (1)$$

where:

- $m(t)$ = mass of water vapor in Cluster atmosphere, lbs
- $g(t)$ = water vapor generation rate in Cluster, lbs/hr
- $r(t)$ = water vapor removal rate from Cluster, lbs/hr

$m(t)$ is given by the ideal gas law:

$$m(t) = \frac{VM}{RT} p(t) \quad (2)$$

where:

- $p(t)$ = water vapor partial pressure, lbs/in²
- V = volume of Cluster = 12,199 ft³
- M = molecular weight of water = 18
- R = ideal gas constant = 10.73 psia ft³/mole °R
- T = atmospheric temperature = 70° F = 530°R

Differentiating (2)

$$\frac{dm(t)}{dt} = \frac{VM}{RT} \frac{dp(t)}{dt} = g(t) - r(t) \quad (3)$$

or

$$\frac{dp(t)}{dt} = \frac{RT}{VM} [g(t) - r(t)] \quad (4)$$

CASE I: DEW POINT $\leq 40^\circ$ F

For the case when the dew point is less than 40° F, the only source of water removal from the atmosphere is the pre-drying bed of the molecular sieve. Defining F as the volumetric flow rate through the molecular sieve ($F = 360 \text{ ft}^3/\text{hr}$), the water removal rate, $r(t)$, becomes

$$r(t) = F \cdot \frac{m(t)}{V} = \frac{FM}{RT} p(t) \quad (5)$$

For a constant water generation rate, $g(t) = G$, substitution of (5) into (4) yields:

$$\frac{dp(t)}{dt} = \frac{RT}{VM} [G - \frac{FM}{RT} p(t)] \quad (6)$$

Solving (6) for $p(t)$ gives

$$p(t) = \frac{RTG}{FM} (1 - e^{-Ft/V}) \quad (7)$$

Using the previously defined values for R, T, F, M, and V, equation (7) becomes for the two values of G:

$$G = 6.6 \text{ lbs/day: } p(t) = .242 (1 - e^{-.0296t}) \text{ lbs/in}^2; t \text{ in hours}$$

$$G = 15.6 \text{ lbs/day: } p(t) = .571 (1 - e^{-.0296t}) \text{ lbs/in}^2; t \text{ in hours}$$

CASE II: DEW POINT > 40° F

When the atmospheric dew point is greater than 40° F, water is removed in both the AM condensing heat exchanger and the pre-drying bed of the molecular sieve. An approximate equation describing the water removal rate (lbs/hr) of the condensing heat exchanger as a function of the water vapor partial pressure of the atmosphere is given below (Ref. 2).

$$r_{\text{chx}}(t) = 7.13 p(t) - .871, \text{ lbs/hr} \quad (8)$$

Assuming the air flow out of the condensing heat exchanger is saturated at 40° F (water vapor partial pressure equals .122 lbs/in²), the water removed in the predrying bed of the molecular sieve becomes

$$r_{\text{ms}}(t) = F \cdot \frac{m(t)}{V} = \frac{FM}{RT} p(t) \quad (9)$$

$$r_{\text{ms}}(t) = \frac{(360)(18)(.122)}{(10.73)(530)} = .137 \text{ lbs/hr} \quad (10)$$

The total water removal rate for the Cluster is simply the sum of $r_{\text{ms}}(t)$ and $r_{\text{chx}}(t)$.

$$r_{\text{T}}(t) = 7.13 p(t) - .734, \text{ lbs/hr} \quad (11)$$

Once again letting $g(t) = G$, and substituting (11) into equation (4) yields

$$\frac{dp(t)}{dt} + 7.13 \frac{RT}{VM} p(t) = \frac{RT}{VM} (G + .734) \quad (12)$$

Solving for $p(t)$ and substituting for the known constants gives

$$p(t) = \frac{G + .734}{7.13} \left[1 + \left(\frac{.122(7.13)}{G + .734} - 1 \right) e^{-.185t} \right] \quad (13)$$

For the two values of G , (13) becomes

$$G = 6.6 \text{ lbs/day: } p(t) = .14(1 - .13 e^{-.185t}) \text{ lbs/in}^2, t \text{ in hrs}$$

$$G = 15.6 \text{ lbs/day: } p(t) = .194(1 - .372 e^{-.185t}) \text{ lbs/in}^2, t \text{ in hrs}$$

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REFERENCES

1. Minutes of the 10th AAP ECS/Thermal Subpanel Meeting, May 6, 1969.
2. AM Technical Briefing at NASA MSFC, 31 October - 1 November, 1968.
3. "A Review of Water Reclamation Systems for AAP," Bellcomm Memorandum for File, J. J. Sakolosky, February 1, 1968.